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Numerical Simulation of Non-Isothermal CO_2 Injection Using the Thermo-Hydro-Mechanical Code CODE_BRIGHT

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Storage of carbon dioxide (CO_2) in deep geological formations is considered an option for reducing greenhouse gas emissions to the atmosphere. Injecting CO_2 into aquifers at depths greater than 800 m brings CO_2 to a supercritical state where its density is large enough to ensure an efficient use of pore space. However, CO_2 will always be lighter than the resident brine. Therefore, it will flow along the top of the aquifer because of buoyancy. Thus, suitable aquifers should be capped by a low-permeability rock to avoid CO_2 migration to upper aquifers and the surface.

Therefore, ensuring mechanical stability of the caprock is critical to avoid CO_2 leakage. Yet, CO_2 injection can result in significant pressure buildup, which affects the stress field and may induce large deformations (Vilarrasa et al., 2010b). These can eventually damage the caprock and open up new flow paths. Moreover, inflowing CO_2 may not be in thermal equilibrium with the aquifer, which induces stress changes that may affect the caprock stability.

We use the coupled thermo-hydro-mechanical finite element numerical code CODE_BRIGHT (Olivella et al., 1994, 1996) to simulate these processes. We have extended the code to simulate CO_2 as a non-wetting phase. To this end, we have implemented the Redlich-Kwong equation of state for CO_2. As a first step, two-phase flow studies (Vilarrasa et al., 2010a) were carried out. Next, coupled hydro-mechanical simulations were performed (Vilarrasa et al., 2010b). Finally, we have implemented CO_2 thermal properties to simulate non-isothermal CO_2 injection in deformable deep saline formations.

Coupled thermo-hydro-mechanical simulations of CO_2 injection produce a region in thermal equilibrium with the injected CO_2. The thermal transition is abrupt. A small rise in the temperature of the supercritical CO_2 region is produced by the exothermal reaction of CO_2 dissolution into the brine. An induced thermal stress change due to thermal contraction/expansion of the rock takes place in the region affected by the CO_2 injection temperature. This can compromise the stability of preexisting fractures and trigger microseismic events.

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